

# Pain and Stress

## General Topics & Web Resources

### Anatomy, Neurophysiology, and Pharmacology Studies & Web Resources

## General Topics

Aabel JP, DePauw N, Joyce J (1991) **Stress of Atlantic salmon caused by handling and grading.** *Aquaculture and the Environment. Special Publication, European Aquaculture Society.* 14:1

NAL Call No. SH138.S64

Treatment of fish induces stress to the individuals. Indications of stress can be abnormal behavior like spontaneous migrations towards one part of the cage, increased breathing activity etc., but stress can also lead to increased susceptibility to pathogens and possible higher mortality. Several papers have demonstrated that certain blood parameters can be used as indicators of the physiological condition of the fish. Examining blood samples can give a fairly good impression of the stress level of the fish. Stress in cultured salmon can be associated with different handling procedures like anaesthesia, smoltification, grading, sorting, weighing, but can also be associated with fluctuations in temperature, pH, oxygen, etc. For reasons mentioned in the first chapter it is obviously very important to handle the fish as carefully as possible to minimize the added stress. Through a series of experiments we have tried to quantify the stress added through handling and grading of various sized Atlantic salmon (*Salmo salar*). Both seawater and freshwater have been used. Analyses included concentrations of lactate, glucose, hematocrit, hemoglobin and plasmachloride. *Descriptors:* fish physiology, biological stress, mortality causes, handling, fish culture, cultured organisms, hematology, *Salmo salar*

ASFA; Copyright © 2003, FAO

Adcock PJ, Dando PR (1983) **White muscle lactate and pyruvate concentrations in rested flounder, *Platichthys flesus* and plaice, *Pleuronectes platessa* : A re-evaluation of handling and sampling techniques.** *Journal of the Marine Biological Association of the United Kingdom.* Plymouth. 63(4):897-903

NAL Call No. 442.9 M331

Rapid fixing of skeletal muscle by a “freeze-clamp” technique results in up to a 3-fold lower

lactate, a slightly higher pyruvate concentration and a 2- to 4-fold decrease in lactate/pyruvate ratio, to the lowest value yet recorded for fish muscle, when compared with the more usual method of direct immersion in liquid nitrogen. This is attributed to the faster cooling rate of freeze-clamped muscle minimizing "sampling anoxia". Immobilizing fish either by anaesthetic or stunning produces no significant change in metabolite levels. It is concluded that it is relatively easy to handle quiescent flatfish, but light anaesthesia ensures no muscular activity.

*Descriptors:* muscles, biochemical composition, analytical techniques, biochemistry, metabolites, fixation, *Platichthys flesus*, *Pleuronectes platessa*, Pisces, *Pleuronectidae*, lactate, pyruvate, freeze-clamp technique

ASFA; Copyright © 2003, FAO

AVMA (2002) **2001 AVMA Animal Welfare Forum, Pain Management**, Hyatt Regency Chicago, Chicago, Illinois, USA, 14 October, 2001. *Journal of the American Veterinary Medical Association*. 221(2):201-237.

NAL Call No. 41.8 AM3

The proceedings cover topics on pain management and welfare implications and medical and case reports in domestic animals, including dogs, cats, laboratory animals, horses and cattle. Topics include evaluation of an ELISA to measure serum thyroxine in dogs and cats, treatment of feline *Haemobartonella felis* with enrofloxacin, effect of fipronil in flea allergic dermatitis-affected cats, acute necrotizing dermatitis and septicaemia in a cat, melanoma in a dog, lufenuron treatment of fungal endometritis in mares, udder cleft dermatitis and sarcoptic mange in a dairy herd, congenital protoporphyria in a calf and surgical removal of a seminoma from a black sea bass (*Centropristis striata*).

*Descriptors:* animal welfare, blood chemistry, calves, congenital abnormalities, dairy herds, dermatitis, drug therapy, ELISA, endometritis, enrofloxacin, insect growth regulators, insecticides, laboratory animals, melanoma, neoplasms, pain, scabies, surgery, therapy, thyroxine, Perciformes, Osteichthyes, fishes, aquatic organisms, aquatic animals

Copyright © 2003, CAB International.

Braune HJ, Gronow G (1975) **Temperature as a stressor in *Idus idus* L. (Teleostei).**

*Zoologischer Anzeiger*. 194:22-34

NAL Call No. 410 Z7

Effects of temp stimuli on substrate contents of the epaxial muscle in *I. idus* (6-7cm) have been studied. Glucose and glucose-6-phosphate content, and the lactate: pyruvate ratio at constant temps were similar in fish acclimated to 15 or 20°C. Both increase and decrease of acclimation temp (AT) from this range generally raised the contents of the substrates mentioned and of the lactate: pyruvate ratio. Pyruvate, however, showed a minimum both at AT 6°C and AT 30°C. The effects of AT 30°C generally exceeded those of AT 6°C, indicating a permanent stress caused by the high constant temp. An abrupt transfer in a stage of light anaesthesia (tricaine methanesulfonate, MS 222) from AT 20°C both to 6 and 30°C for 30min caused an increase of the lactate: pyruvate ratio of {approx} 100%. The values remained high for several hrs even after the fish returned to normal at AT 20°C,

reflecting stress effects. Alternating temps (15 /25°C; 12h/12h) generally raised the substrate contents of *I. dius* (AT 15°C) in the first 10 days. The significant increase of the lactate: pyruvate ration indicates a situation of stress, which is caused mainly by the periodical change of temp and not by the absolute values of the 2 alternating temps. After 10 days alternating temps the values decreased and showed a tendency to reach a constant lower level. The fish seemed to be accustomed to the alternating temp change. The data show that changes in the substrate contents of the epaxial muscle in *I. idus* are an indicator of stress as caused by constant temps and abrupt or alternating temperature changes.

*Descriptors:* temperature effects, fatigue, musculoskeletal system, *Idus idus*  
ASFA; Copyright © 2003, FAO

Carmichael GJ, Tomasso JR, Simco BA, Davis KB (1984) **Characterization and alleviation of stress associated with hauling largemouth bass.** *Transactions of the American Fisheries Society.* 113(6):778-785

NAL Call No. 414.9 AM3

Stress and mortality associated with truck transport of largemouth bass *Micropterus salmoides* were characterized during and after simulated hauling periods of up to 30 hours at a density of 180 g fish/liter of water. Generally, "transported" fish had significantly elevated concentrations of plasma glucose and cortisosteroids and decreased plasma chloride concentrations and osmolality. Significant mortality was associated with hauls of 24 and 30 hours (38% and 83-92%, respectively). Plasma characteristics returned to near-normal 3-28 days after being hauled; recover time generally was related to length of haul and associated mortality. Stress was reduced significantly and mortality was eliminated when fish were treated for diseases, held 72 hours without food before they were loaded, anesthetized before they were loaded, hauled at a cool temperature in physiological concentrations of salts with an antibiotic and a mild anesthetic, and allowed to recover in the same medium less the anesthetic.

*Descriptors:* fish handling, transportation, mortality causes, biological stress, stocking (organisms), *Micropterus salmoides*, biochemistry, alleviation  
ASFA; Copyright © 2003, FAO

Carragher JF, Rees CM (1994) **Primary and secondary stress responses in golden perch, *Macquaria ambigua*.** *Comparative Biochemistry and Physiology, A.* 107A(1):49-56

NAL Call No. QP1.C6

Golden perch (*Macquaria ambigua*), a species of Australian freshwater fish, were subjected to a number of simple stress procedures. Bloodsamples were taken and levels of commonly measured primary and secondary stress response parameters (cortisol, glucose and lactate) were determined. Anaesthesia and exertion of fish prior to bloodsampling affected resting levels of some of the parameters measured. Wild and aquarium-acclimated golden perch had low plasma cortisol levels (< 2 ng/ml). Most fish appeared to adapt well to aquarium

conditions, although occasional fish showed indications of being chronically stressed. Golden perch responded quickly to stress (< 5 min), with increased plasma levels of cortisol and lactate. In contrast glucose levels did not increase until at least 10 min after the stress was initiated; by 30 min, however, the typical hyperglycaemic response was observed. Golden perch recover rapidly from acute stress (< 2.5 hr). Golden perch seem to acclimate quickly to conditions of chronic stress.

*Descriptors:* biological stress, hormones, glucose, blood, acclimation, response analysis, *Macquaria ambigua*

ASFA; Copyright © 2003, FAO

Erdmann C (1999) *Schmerzempfinden und Leidensfähigkeit bei Fischen. Eine Literaturübersicht. [Ability of Fishes to Feel Pain and to Suffer, a Review]*. Tierärztliche Hochschule, Hannover Germany. 155 pp. (In German, with English summary)

*Descriptors:* animal welfare, pain, fishes, aquatic animals

Erikson U, Sigholt T, Seland A (1997) **Handling stress and water quality during live transportation and slaughter of Atlantic salmon (*Salmo salar*)**. *Aquaculture* 149(3-4):243-252

NAL Call No. SH1 A6

Atlantic salmon (*Salmo salar*), mean weight 5.1 kg, were transported live for 1.5 h by a well-boat (fish density 125 kg/m<sup>3</sup>) from the seacage to a fish processing plant and then kept in the well-boat for 4 h prior to slaughter. Anaerobic white muscle activity due to handling stress during fish loading at the cage, after shipment immediately before slaughter, and after the fish had passed the slaughter line, was evaluated using high-energy phosphates and IMP, the [ATP:IMP] ratio, adenylate energy charge together with pH and redox potential measured directly in the muscle. Water quality parameters, pH, salinity, temperature, dissolved oxygen, carbon dioxide, total carbonate carbon, total alkalinity, ammonia and ammonium were monitored at the cage, during shipment, and in the carbon dioxide anaesthesia tank during commercial fish slaughter. No dramatic effects of handling stress were found, indicating that transport and slaughtering did not have an adverse effect on flesh quality. The results were explained by the ability of the well-boat to maintain good seawater quality during transport, to a quick bulk netting of the fish from well-boat to the slaughter line and to an efficiently run carbon dioxide anaesthesia-tank that minimised struggling prior to killing.

*Descriptors:* biological stress, fish handling, transportation, fish culture, cage culture, processing fishery products, aquaculture products, *Salmo salar*

ASFA; Copyright © 2003, FAO

Kestin SC (1994) *Pain and Stress in Fish*. Royal Society for the Prevention of Cruelty to Animals. Amended. Horsham, West Sussex : RSPCA. 36 p.

NAL Call No. SH177.S75K47 1994

*Descriptors:* fishes, pain, fish culture, animal welfare

Lines JA, Frost AR (1999) **Review of opportunities for low stress and selective control of fish.** *Aquaculture Engineering.* 20(4):211-230

Routine inspection and selective control of livestock is an integral part of animal agriculture benefiting both animal welfare and profitability. Appropriate developments in this field may therefore also be expected within fin fish farming. Equipment enabling some subsurface inspection of fish stocks has recently appeared on the market but this is as yet unmatched by equipment which would enable subsurface selective interaction for the purpose of sampling, further inspection or selective application of remedial measures. Currently available non selective fish control techniques are reviewed and some potential methods for selective control are considered. Since most forms of selective control must rely on fish's response to signals the paper is organised on the basis of the sensory systems that might be used. A brief introduction to each system is given followed by a review of any current control techniques and possibilities for developing selective control systems.

*Descriptors:* fish inspection, biological stress, sense functions, control

ASFA; Copyright © 2003, FAO

Meyer WF, Cook PA (1996) **An assessment of the use of low-level aerobic swimming in promoting recovery from handling stress in rainbow trout.** *Aquaculture International.* 4 (2):169-174

NAL Call No. SH1.A627

Transportation and handling may stress fish (Barton and Peter, 1982; Barton et al., 1986), leading to the undesirable consequence that fish are unloaded from transport units in a stressed condition (Barton et al., 1980; Specker and Schreck, 1980). Characteristically, such stress results in alterations to both behaviour (Sigismondi and Weber, 1988) and physiological state (Mazeaud et al., 1977), which may give rise to transport mortality (Wedemeyer, 1976). Consequently, economic and ethical considerations have prompted numerous studies into methods that reduce transport stress (e.g. Wedemeyer, 1972; Barton and Peter, 1982; Carmichael et al., 1984; Robertson et al., 1988) and the manipulation of the transport water osmolality, cold water transport, and anaesthetic treatment prior to transport, have shown some success. All of the aforementioned methods of fish transport reduce the magnitude of transport stress, but little work has focused on promoting stress recovery. Since the initial loading of fish into the transport container is the most stressful component of transport (Miles et al., 1974; Specker and Schreck, 1980), we were curious to know if the recovery process could be initiated during transport itself, leading to the arrival of fish in a less stressed condition. It was examined whether low-level aerobic swimming following handling stress would hasten stress recovery in rainbow trout (*Oncorhynchus mykiss*) over that of unswum fish.

*Descriptors:* aquaculture techniques, biological stress, freshwater fish, swimming, *Oncorhynchus mykiss*

ASFA; Copyright © 2003, FAO

Moberg GP, Mench JA (Eds) (2000) *The Biology of Animal Stress: Basic Principles and Implications for Animal Welfare*. 377 pp. CABI Publishing Wallingford, UK  
NAL Call No. QP82.2 S8 B55 2000

This book brings together a range of scientific perspectives from biomedical research on stress and welfare, and assesses new approaches to conceptualizing and alleviating stress. While much of the focus is on conventional farm animals, there is also consideration of fishes, laboratory animals and zoo animals. The 30 contributors include leading authorities from North America, Europe, New Zealand and Australia. This book is invaluable for advanced students and researchers in animal behaviour, animal welfare, animal production, veterinary medicine and applied psychology. For more information see the CABI Publishing online bookshop (<http://www.cabi.org/Bookshop/>).

*Descriptors:* stress, biology, animal welfare, animal behaviour

Copyright © 2003, CAB International.

Muiswinkel WB van (1999) **The interaction between immune competence and stress responses in relation to fish health problems.** *Fourth Symposium on Diseases in Asian Aquaculture: Aquatic Animal Health for Sustainability November 22-26, 1999, Cebu International Convention Center, Waterfront Cebu City Hotel, Cebu City, Philippines.*

Note: Book of abstracts.

NAL Call No. SH171 S96

It is known that severe and chronic stress is unavoidable during standard procedures in aquaculture. These conditions may lead to acute mortalities or losses caused by diseases. Improving the resistance to disease and/or stress by genetic means is an attractive approach to reduce these widespread welfare problems in aquaculture. However, genetic selection for one type of response may affect the other, due to the delicate balance between the neuroendocrine system and the immune system. To our knowledge these possible negative effects of selection have not been investigated in fish. Recent results from a multidisciplinary research program (supported by the Dutch SLW/LNV priority program) will be reviewed. The program consists of three closely related and interdependent projects aimed at the analysis of specific carp (*Cyprinus carpio*) strains selected for either stress response or immune competence for the following aspects: 1) The physiological responses to a stressor (crowding), which is typical for an aquaculture situation (Fish Culture & Fisheries Group, Wageningen Agricultural University, NL); 2) The modulating effect of a stressor on the genetically determined differences in immune responsiveness (Cell Biology & Immunology Group, Wageningen Agricultural University, NL); 3) The quantitative analysis of the stress response and of immuno-neuro-endocrine interactions (Dept of Animal Physiology, University of Nijmegen, NL).

*Descriptors:* fish culture, immunity, genetics, selective breeding, biological stress, animal physiology, husbandry diseases, disease resistance, *Cyprinus carpio*

ASFA; Copyright © 2003, FAO

Oidtmann B, Hoffmann RW (2001) **Schmerzen und Leiden bei Fischen[Pain and suffering in fish].** *Berliner und Munchener Tierarztliche Wochenschrift*. 114(7-8): 277-

82. (In German with an English summary)

NAL Call No. 41.8 B45

The question on the capability of fish to feel pain and of suffering are still subject of discussion nowadays. In the article presented, the information available in the literature to date is summarised. Based on this knowledge, the conclusion is drawn that fish are capable of feeling pain and that they are able to suffer in the sense of the word as used in the German animal welfare law. ( 66 Refs.)

*Descriptors:* fishes, physiology, pain, veterinary, animal welfare, legislation and jurisprudence, autonomic nervous system, physiology, Germany, pain prevention and control, stress

Peters G (1988) **Schmerz und Stress bei Fischen. [Stress and pain in fish.]** *Deutsche Tierärztliche Wochenschrift.* 95(2):60-63. (In German with an English summary). ISSN: 0341-6593

*Descriptors:* fishes, stress, pain, animal welfare, animal health, animals, aquatic animals, aquatic organisms, disorders, dysregulation, functional disorders, injurious factors, physiological, functions

Rose JD (2002) **The neurobehavioral nature of fishes and the question of awareness and pain.** *Reviews in Fisheries Science.* 10(1):1-38.

NAL Call No. SH1.R425

This review examines the neurobehavioral nature of fishes and addresses the question of whether fishes are capable of experiencing pain and suffering. The detrimental effects of anthropomorphic thinking and the importance of an evolutionary perspective for understanding the neurobehavioral differences between fishes and humans are discussed. The differences in central nervous system structure that underlie basic neurobehavioral differences between fishes and humans are described. The literature on the neural basis of consciousness and of pain is reviewed, showing that: (1) behavioral responses to noxious stimuli are separate from the psychological experience of pain, (2) awareness of pain in humans depends on functions of specific regions of cerebral cortex, and (3) fishes lack these essential brain regions or any functional equivalent, making it untenable that they can experience pain. Because the experience of fear, similar to pain, depends on cerebral cortical structures that are absent from fish brains, it is concluded that awareness of fear is impossible for fishes. Although it is implausible that fishes can experience pain or emotions, they display robust, nonconscious, neuroendocrine, and physiological stress responses to noxious stimuli. Thus, avoidance of potentially injurious stress responses is an important issue in considerations about the welfare of fishes.

*Descriptors:* pain, nociception, stress, awareness, anthropomorphism, neurophysiology, literature reviews, behavioural responses, biological stress, nature conservation

<http://www.news-press.com/multimedia/documents/fishpain/fishpain.pdf>

Schreck CB (2000) **Accumulation and long-term effects of stress in fish.** (Eds:) Moberg GP, Mench JA. *The Biology of Animal Stress: Basic Principles and Implications for Animal*

*Welfare*. CABI Publishing, Wallingford, UK. p.147-158.

NAL Call No. QP82.2 S8 B55 2000

*Descriptors*: stress, stress response, physiology, performance, fishes, aquatic animals

Wells RMG, Tetens V, Devries AL (1984) **Recovery from stress following capture and anaesthesia of Antarctic fish: Haematology and blood chemistry**. *Journal of Fish Biology*. 25(5):567-576

NAL Call No. QL614 J68

Qualitative changes in haematology and blood chemistry of the giant Antarctic cod, *Dissostichus mawsoni*, were followed during recovery from the stresses of capture and cannulation under MS 222 anaesthesia. Cannulation with anaesthesia resulted in a transient rise in haematocrit and haemoglobin concentration, and a fall in blood pH. These changes returned to stable values 8-24 h later. Blood lactate and mean corpuscular haemoglobin concentration remained near to resting values. Experiments with the smaller species, *Pagothenia borchgrevinki*, indicated that erythrocyte swelling, elevated blood lactate, and changes in ATP concentration were delayed manifestations of severe agitational stress. The significance of these findings is discussed in relation to oxygen transport in fish having low metabolic rates, and also in relation to widely used techniques for sampling blood.

*Descriptors*: hematology, biological stress, *Dissostichus mawsoni*, *Pagothenia borchgrevinki*

ASFA; Copyright © 2003, FAO

## ***Web Resources:***

**Aspects of Animal Welfare and Aquaculture - A Compendium of Selected Literature** by Richard D. Moccia and Kristopher P. Chandroo; Aquaculture Centre, University of Guelph, Guelph, Ontario, Canada

<http://www.aps.uoguelph.ca/~aquacentre/aec/publications/welfare-bib.html>

### **Do Fish Feel Pain?**

**Dr. James D. Rose**

[http://www.cotrout.org/do\\_fish\\_feel\\_pain.htm](http://www.cotrout.org/do_fish_feel_pain.htm)

<http://www.anglingmatters.com/DrRoseReport.pdf>

### **Pain in Fish**

<http://www.vet.ed.ac.uk/animalwelfare/Fish%20pain/Contents.htm>

---

## Anatomy, Neurophysiology and Pharmacology Studies

Allen JL, Dawson VK, Hunn JB (1999) **Biotransformation of selected chemicals by fish.** Presented at: 176. Meet. American Chemical Society, Pesticide Chemistry Division; Miami Beach, FL (USA); 11 Sep 1978. In: *Pesticide and Xenobiotic Metabolism in Aquatic Organisms. Based on a symposium sponsored by the Division of Pesticide Chemistry at the 176th Meeting of the American Chemical Society, Miami Beach, Florida, September 11-17, 1978.* No. 99. Publ. by: American Chemical Society; Washington, DC (USA), 1979, p. 121-129, ACS Symp. Ser.

NAL Call No. QD1 A45 No. 99

Biotransformation of selected chemicals by freshwater fish is accomplished through a diversity of biochemical pathways. Biliary and renal excretion of glucuronide conjugates of two lampricides, 3-trifluoromethyl-4-nitrophenol (TFM) and 2',5'-dichloro-4'-nitrosalicylanilide (Bayer 73), have been demonstrated. Glucuronide conjugation has also been demonstrated with the fish anesthetic, 2-amino-4-phenylthiazole (Piscaine).

Preliminary studies have indicated that fish are capable of hydrolyzing Bayer 73 to two fragments, 5-chloro-salicylic acid and 2-chloro-4-nitroaniline. Hydrolysis of the ester linkage of methane sulfonate of m-aminobenzoic acid ethyl ester (MS-222) to form m-aminobenzoic acid has been shown in freshwater and saltwater fish. Amino groups in MS-222 and Piscaine are subject to N-acetylation. Most of the acid metabolites of the fish anesthetics are excreted renally. Dealkylation of a substituted amine was shown by the stepwise deethylation of dinitramine (NSUP-3, NSUP-3 -diethyl-2,4-dinitro-6-trifluoromethyl-m-phenylenediamine) in carp (*Cyprinus carpio*). Fish are also capable of biotransformation involving substitution; fish exposed to Thanite (isobornyl thiocynoacetate) apparently release cyanide by substituting a methyl group to form isobornyl- -(methylthio)acetate.

*Descriptors:* chemical pollutants, pollution effects, *Cyprinus carpio*, Cyprinidae, Pisces ASFA; Copyright © 2003, FAO

Allen JL, Luhning CW, Harman PD (1972) **Residues of MS 222 in Northern pike, muskellunge and walleye.** *Technical Paper. Bureau of Sport Fisheries and Wildlife. US Fish and Wildlife Service. Washington DC.* 45:3-8

Residues of MS-222 (tricaine methanesulfonate) in muscle tissue of Northern pike, muskellunge, and walleye following anesthesia were measured by a modified Bratton-Marshall colorimetric method and confirmed by TLC. The residues dissipate rapidly from the muscle when fish are withdrawn from the anesthetic and are near the background

readings of the controls within 24 hours.

ASFA; Copyright © 2003, FAO

*Descriptors:* MS 222, Northern pike, muskellunge, walleye, anesthetic

Allen JL, Luhnung ChW, Harman PD (1970) **Identification of MS 222 residues in selected fish tissues by thin layer chromatography.** *Investigations in Fish Control.* 41:1-7

NAL Call No. SH157.7 I58

MS-22, a commonly used fish anesthetic, reacts with the Bratton-Marshall reagents to form a winered dye. Residues of MS-222 determined by this reaction are not distinguished from other primary aromatic amines. TLC was used to identify MS-222 in the presence of background primary aromatic amines in fish muscle, brain, and blood. This method, in which the Bratton-Marshall reaction is used to visualize the spots, gave both the specificity of the Bratton-Marshall reaction for primary aromatic amines and the Rf of MS-222 as tools for identification of the residus. Recoveries of 25 to 60% were obtained in muscle samples spiked with 2 to 10 ppm of MS-222. Quantitative estimation was difficult in samples spiked with 2 ppm or less, but presence of MS-222 residues could be confirmed in samples spiked with as little as 0.2 ppm. Since the meta-aminobenzoate ester can be identified at these concentrations, this should be a useful ancillary or confirmatory method for determining the rate of disappearance of drug residues in fish flesh and obtaining data for clearance and registration of the anesthetic with the Food and Drug Administration.

*Descriptors:* MS-222, fish, tissues, anesthesia, analgesia, concentration, residues, chromatography,

ASFA; Copyright © 2003, FAO

Beaumont MW, Butler PJ, Taylor EW (1995) **Plasma ammonia concentration in brown trout in soft acidic water and its relationship to decreased swimming performance.**

*Journal of Experimental Biology.* 198(10):2213-2220

NAL Call No. 442.8 B77

Adult brown trout (300-600 g) were acclimated for 2 weeks to an artificial soft water ( $\text{Ca}^{2+}$ , 50  $\mu\text{mol l}^{-1}$ ) and maintained at either 5°C (October to March) or 15°C (May to August). Following insertion of a cannula into the dorsal aorta under MS-222 anaesthesia and a recovery period of 2 days, the fish were exposed to a 4 day episode of sub-lethal copper levels at pH5 or kept at control conditions of pH7 without copper. The copper concentrations had been predetermined by toxicity testing and were approximately 0.47  $\mu\text{mol l}^{-1}$  at 5°C and 0.08  $\mu\text{mol l}^{-1}$  at 15°C. At 5°C, a group of fish was also exposed to approximately 0.08  $\mu\text{mol l}^{-1}$  copper at pH5. Plasma total ammonia ( $T_{\text{amm}}$ ) concentration was significantly elevated by exposure to copper and pH5. In resting trout exposed to the appropriate sub-lethal copper concentration at pH5,  $T_{\text{amm}}$  was six and 7.5 times greater at 5

and 15°C, respectively, than those of control trout at the respective temperatures. Although unconfirmed, an elevation of ammonia production alone seems unlikely to account for such substantial increases. From previous studies, there is little evidence of impairment of respiratory gas exchange in trout exposed to these copper concentrations and yet, in the acidic test waters, the gradient of NH<sub>3</sub> partial pressure between fish and water was 5.5-6 times greater than that under control conditions. Swimming performance determined by the critical swimming speed ( $U_{crit}$ ) was reduced by copper and acid exposure, and a significant relationship existed between  $U_{crit}$  and the plasma ammonia concentration of exercised trout. Ammonium ions influence several key enzymes involved in energy metabolism, and elevated ammonia levels might, therefore, reduce the capacity of muscle to exercise. Alternatively, ammonia may have affected the nervous coordination of exercise either centrally or by disrupting peripheral motor innervation.

*Descriptors:* swimming, copper, pH effects, ammonia, haematology, pollution effects, hypoxia, *Salmo trutta*, pH, hematology, toxicity testing, trout, sublethal effects, hydrogen ion concentration, toxicity, water pollution effects

ASFA; Copyright © 2003, FAO

Belanger SE, Schurr K, Allen DJ, Gohara AF (1986) **Effects of chrysotile asbestos on coho salmon and green sunfish: Evidence of behavioral and pathological stress.**

*Environmental Research.* 39(1):74-85

NAL Call No. RA565 A1E5

The effects of chrysotile asbestos on larval coho salmon (*Oncorhynchus kisutch*) and juvenile green sunfish (*Lepomis cyanellus*) were investigated at levels approximating those reported in the Great Lakes basin (10<sup>6</sup> fibers/liter). Behavioral stress effects, such as loss of rheotactic position and balance, were observed in salmon exposed at 3.0 x 10<sup>6</sup> fibers/liter and in sunfish exposed at 1.5 and 3.0 x 10<sup>6</sup> fibers/liter. Coho larvae at 1.5 x 10<sup>6</sup> fibers/liter were significantly more susceptible to an anesthetic stress test, becoming ataxic and losing equilibrium faster than control cohorts. Two of 106 larvae exposed at 3.0 x 10<sup>6</sup> fibers/liter developed tumorous swellings and three additional fish developed coelomic distentions. Cytological examination of ventral epidermal tissue revealed cellular histolysis, and evidence by transmission electron microscopy confirmed the presence of asbestos in the salmon larvae. Distortion of the lateral line region in asbestos-treated coho salmon was linked to behavioral and orientational aberrations.

*Descriptors:* asbestos, behavior, pathology, toxicity, *Oncorhynchus kisutch*, *Lepomis cyanellus*, effects on

ASFA; Copyright © 2003, FAO

Benoit E, Laurent D, Mattei C, Legrand AM, Molgo J (2000) **Reversal of Pacific ciguatera toxin-1B effects on myelinated axons by agents used in ciguatera treatment.** *First*

*Meeting on Ichthyology in France, RIF 2000. Cybium – Paris. 24(3S):33-40 ISSN: 1399-0974*

Ciguatera fish poisoning is a distinctive form of ichthyosarcotoxism characterised mainly by gastrointestinal and neurological disturbances. The ciguatoxins, responsible for this poisoning, are complex polyethers produced by toxic strains of the dinoflagellate *Gambierdiscus toxicus*. These toxins are increased to dangerous levels for man during their transmission through herbivorous and carnivorous fish, various species being contaminated. The known molecular target of ciguatoxins is the voltagegated Na<sup>+</sup> channel. During the action of these toxins, the permanent opening of channels, at the resting membrane potential, produces a continuous entry of Na<sup>+</sup> ions in excitable cells causing a marked increase in membrane excitability and in cellular volume. To precise the neurocellular bases of the efficacy of some agents used in clinical and traditional treatments of ciguatera, their effects were studied on frog myelinated axons exposed to Pacific ciguatoxin-1B (CTX-1B). During the action of this toxin, the increase in axonal volume and membrane excitability was reversed by lidocaine (a local anaesthetic), by CaCl<sub>2</sub> and by hyperosmotic external solutions (containing D-mannitol, sucrose or tetramethylammonium chloride). The CTX-1B-induced hyperexcitability of the membrane was also reversed by extracts of *Argusia argentea* leaves or *Davallia solida* rhizomes, used traditionally in New-Caledonia. It is concluded that the various agents studied are able to counteract the neurocellular effects of CTX-1B in myelinated axons. These results are of particular interest since they provide a scientific basis to understand the beneficial action of therapeutic agents used in the treatment of ciguatera fish poisoning.

*Descriptors:* ciguatoxin, fish poisoning, ions, therapy  
ASFA; Copyright © 2003, FAO

Benzer TI, Raftery MA (1972) **Partial characterization of a tetrodotoxin-binding component from nerve membrane.** *Proceedings of the National Academy of Sciences, USA.* 69(12):3634-3637

NAL Call No. 500 N21P

Tetrodotoxin from Japanese puffer fish has been labeled with tritium and purified from the crude mixture obtained. The interaction between the purified [<sup>3</sup>H]tetrodotoxin and membrane suspensions from the olfactory nerve of long-nosed garfish has been investigated by equilibrium dialysis. Tetrodotoxin binds to membrane suspensions with a dissociation constant  $K_D=8.3\text{nM}$ . The nerve preparation binds 42 pmol of [<sup>3</sup>H]tetrodotoxin/g of wet tissue at saturating toxin concentrations. With various hydrolytic enzymes, the binding component is shown to be a protein embedded in a phospholipid environment. The binding is inhibited below pH 4.0 and is not stable towards heat. Tetrodotoxin binding is not inhibited by the local anesthetic, procaine.

*Descriptors:* tetrodotoxin, puffer fish, nerve tissue  
ASFA; Copyright © 2003, FAO

Bernstein JJ (1970) **Anatomy and physiology of the central nervous system.** In: Hoar, W. S. and Randall, D.J. (eds) *Fish Physiology, Vol. IV*, Academic Press, New York, p. 1-78  
*Descriptors:* fish, anatomy, physiology, CNS, central nervous system, neurobiology

Bradford Jr. MR (1995) **Comparative aspects of forebrain organization in the ray-finned fishes: touchstones or not?** *Brain, Behavior and Evolution.* 46:259-274  
*Descriptors:* neurobiology, CNS, comparative evolution, ray-finned fish

Broderius SJ, Kahl M (1985) **Acute toxicity of organic chemical mixtures to the fathead minnow.** *Aquatic Toxicology.* 6(4):307-322

NAL Call No. QH541.5.W3A6

The acute joint toxicity of industrial organic chemicals to the fathead minnow (*Pimephales promelas*) was determined for binary and equitoxic multiple chemical mixtures. Results from binary tests were used to define isobole diagrams. The degree of joint toxic action was determined among 27 chemicals from seven different chemical classes. The slopes of the acute concentration response relationships were quite similar for all test chemicals. This suggests that the mode of acute toxic action for these chemicals is alike though it may not be identical. Intoxication signs of fish exposed to nearly all test chemicals were also similar and indicative of an anesthetic like effect. The results of isobole diagrams for binary mixtures, with 1-octanol as the reference chemical, demonstrated a near concentration additive acute joint action over a wide range of mixture ratios, for each chemical from 7 different classes.

*Descriptors:* organic compounds, synergism, toxicity, chemical pollutants, *Pimephales promelas*, acute toxicity, mixtures

ASFA; Copyright © 2003, FAO

Brown EAB, Franklin JE, Pratt E, Trams EG (1972) **Contributions to the pharmacology of quinaldine (uptake and distribution in the shark and comparative studies).**

*Comparative Biochemistry and Physiology.* 42(1A):223-231

NAL Call No. QP1.C6

(1) Comparative toxicity and anaesthetic conc of quinaldine (2-methylquinoline), 9 related quinolines and 2-methylpyridine were studied in mice and several spp of fish. The compds were administered as methanesulfonate salts. (2) The absorption and excretion rates of quinaldine were similar in fish and the drug was excreted unchanged. (3) The anaesthetic conc in sea water for 2-, 6-, 7-, and 8- methylquinolines in fish was similar, 0.05-0.15 mM. (4) The LD50 values for mice were of the same order of magnitude for all quinolines studied, i.e. 0.5-3 m-moles/kg, i.p.

*Descriptors:* quinaldine, shark, anesthetic, fish, LD50

ASFA; Copyright © 2003, FAO

Butler AB (2000) **Topography and topology of the teleost telencephalon: a paradox resolved.** *Neuroscience Letters*. 293:95-98

NAL Call No. QP351 N3

*Descriptors:* teleost, telencephalon, fish, neurobiology

Carruth LL, Jones RE, Norris DO (2000) **Cell density and intracellular translocation of glucocorticoid receptor-immunoreactive neurons in the Kokanee salmon (*Oncorhynchus nerka kennerlyi*) brain, with an emphasis on the olfactory system.**

*General and Comparative Endocrinology*. 117:66-76

NAL Call No. 444.8 G28

*Descriptors:* neurobiology, glucocorticoid receptor-immunoreactive neurons, Kokanee salmon, *Oncorhynchus nerka kenerlyi*

Cameron AA, Snow PJ, Plenderleith MB (1990) **Organization of the spinal cord in four species of elasmobranch fish: Cytoarchitecture and distribution of serotonin and selected neuropeptides.** *Journal of Comparative Neurology*. 297:201-218

NAL Call No. QP351 J68

*Descriptors:* neurobiology, neurology, CNS, elasmobranch, shark, serotonin, neuropeptides

Coggeshall RE, Leonard RB, Applebaum ML, Willis WD (1978) **Organization of peripheral nerves and spinal roots of the Atlantic stingray, *Dasyatis sabina*.** *Journal of Neurophysiology*. 41:97-107

*Descriptors:* neurology, peripheral nervous system, Atlantic stingray, *Dasyatis sabina*

Corrêa SAL, Corrêa FMA, Hoffmann A (1998) **Stereotaxic atlas of the telencephalon of the weekly electric fish *Gymnotus carapo*.** *Journal of Neuroscience Methods*. 84:93-100

*Descriptors:* neurobiology, telencephalon, CNS, electric fish, *Gymnotus carapo*

Davis RE, Kassel J (1983) **Behavioral functions of the teleostean telencephalon.** In: *Fish Neurobiology. Volume 2: Higher Brain Areas and Functions* (ed. by R.E. Davis & R.G. Northcutt), pp. 238-263. University of Michigan Press, Ann Arbor

*Descriptors:* teleost, telencephalon, neurobiology, behaviour

Demski LS (1983) **Behavioural effects of electrical stimulation of the brain.** In: *Fish Neurobiology. Volume 2: Higher Brain Areas and Functions* (ed. by R.E. Davis and R.G. Northcutt), pp. 317-359. University of Michigan Press, Ann Arbor

*Descriptors:* neurobiology, CNS, brain, behaviour, electrical stimulation

Devor A (2000) **Is the cerebellum like cerebellar-like structures?** *Brain Research Reviews*. 34:149-156

*Descriptors:* neurobiology, cerebellum, telencephalon

Di Marco P, McKenzie DJ, Mandich A, Bronzi P, Cataldi E, Cataudella S (1999) **Influence of sampling conditions on blood chemistry values of Adriatic sturgeon *Acipenser naccarii* (Bonaparte, 1836).** Proceedings of the 3. International Symposium on Sturgeon, Piacenza, Italy, July 8-11, 1997. *Journal of Applied Ichthyology / Zeitschrift fur Angewandte Ichthyologie*. Hamburg, Berlin. 15(4-5):73-77

NAL Call No. QL614.Z44

Data on the blood chemistry of a chondrostean fish, the Adriatic sturgeon (*Acipenser naccarii*), are reported as measured with different sampling procedures, and as related to rearing conditions and age. Serum cortisol, glucose, osmolality, Na<sup>+</sup>, Cl<sup>-</sup>, Ca<sup>2+</sup> and total protein concentrations were measured. Reference values for the blood chemistry of farmed sturgeon were measured on samples from resting undisturbed animals collected via a chronic indwelling catheter in the dorsal aorta that was implanted under anaesthesia. Following 24 h recovery from catheterization, serum cortisol, glucose and osmolality levels were 9.4 ng/ml, 58.8 mg/dl and 261.4 mOsm/kg, respectively. Furthermore, blood samples collected with the chronic indwelling catheters indicated that the surgical procedure of cannulation caused a stress response, with physiological changes that followed a pattern like that described in teleosts. Cortisol, glucose and osmolality were more sensitive to stress than the other variables measured. Sampling by cardiac puncture tended to be associated with elevated serum cortisol levels in older, larger sturgeon, but not in young fish. Greater capture, confinement and handling stress in older, larger, sturgeon may have been responsible for this and other age-related differences in blood chemistry values measured following cardiac puncture. Within the same age class, both rearing conditions and temperature affected cortisol, sodium and total protein concentrations significantly. Anaesthesia did not appear to reduce the degree of stress associated with cardiac puncture but altered serum ion concentrations.

*Descriptors:* haematology, rearing, environmental conditions, biological stress, *Acipenser naccarii*

ASFA; Copyright © 2003, FAO

Dorsen M (1974) **Production of anti-dinitrophenol precipitating antibody in rainbow trout alevins (*Salmo gairdneri*) immunised at one month old.** *Comptes Rendus. Academie des Sciences. Serie D*. 278(24):3151-3152

Month-old rainbow trout alevins, of mean weight 0.15g, were immunised by abdominal injection of dinitrophenol (DNP) combined with keyhole-limpet haemocyanin, under MS-222 anaesthesia. Three months later (at mean body weight 3.0g) serum tested by Ouchterlony's gel diffusion technique with DNP-haemocyanin gave a precipitation reaction

in 10 out of the 28 fish. Thus in an alevin at one month, i. e. before feeding begins, immune competence may already have developed.

*Descriptors:* immunology, *Oncorhynchus mykiss*

ASFA; Copyright © 2003, FAO

Drapeau P, Legendre P (2001) **Neuromuscular transmission on the rebound. Receptors and Channels.** 7(6):491-496 ISSN: 1060-6823

Recent work at the zebrafish neuromuscular junction (NMJ) has shown that positively charged acetylcholine (ACh), at the high concentrations reached in the cleft during neuromuscular transmission, blocks acetylcholine receptors (AChRs) as soon as they open. Thus after two ACh molecules bind and open the channel, a third molecule enters and blocks the pore at a site resembling that for block by local anesthetics, suggesting that ACh is the endogenous anesthetic of the NMJ. Recovery from open channel block results in a rebound synaptic current only after ACh is cleared from the cleft. Kinetic modeling of other AChRs suggests that a rebound current is generated at all vertebrate NMJs, from fish to frogs to mammals. Open channel block prolongs the current at fast zebrafish NMJs in order to more effectively spread charge along the fibers, akin to multiple central synapses spread over dendrites. Together these findings indicate the need for a fundamental revision of current thinking about neuromuscular transmission at many levels, including channel structure, function and pharmacology.

*Descriptors:* nerves, muscles, neurotransmitters, electrophysiology, *Danio rerio*, zebra danio

ASFA; Copyright © 2003, FAO

Echteler SM, Saidel WM (1981) **Forebrain connections in the goldfish support telencephalic homologies with land vertebrates.** *Science.* 212:683-684

NAL Call No. 470 Sci2

*Descriptors:* neurobiology, CNS, goldfish, telencephalon, cerebellum

Ehrensing RH, Michell GF, Kastin AJ (1982) **Similar antagonism of morphine analgesia by MIF-1 and naloxone in *Carassius auratus*.** *Pharmacology Biochemistry and Behavior.* 17:757-761

NAL Call No. QP901 P4

*Descriptors:* morphine, biochemistry, neurobiology, MIF-1, naloxone, *Carassius auratus*

Fibiger HC, Phillips AG (1986) **Reward, motivation, cognition: psychobiology of mesotelencephalic dopamine systems.** In: *Handbook of Physiology. Volume 4; The Nervous System* (e.d by V.B. Mountcastle, F.E. Bloom & S.R. Geiger), pp. 647-675. American Physiological Society. Bethesda, Maryland

*Descriptors:* neurobiology, physiology, psychobiology, mesotelencephalic dopamine

system

Finger TE (1980) **Nonolfactory sensory pathway to the telencephalon in a teleost fish.** *Science*. 210:671-673

NAL Call No. 470 Sci2

*Descriptors:* neurobiology, telencephalon, nonolfactory sensation, teleost

Finger TE (1983) **Organization of the teleost cerebellum.** In: *Fish Neurobiology. Volume 1: Brain Stem and Sense Organs* (ed. by R.G. Northcutt & R.E. Davis) pp.261-284.

University of Michigan Press, Ann Arbor

*Descriptors:* neurobiology, teleost, telencephalon, cerebellum

Fuller JD, Scott DBC, Fraser R (1976) **The reproductive cycle of *Coregonus lavaretus* (L) in Loch Lomond, Scotland, in relation to seasonal changes in plasma cortisol concentration.** *Journal of Fish Biology*. 9(2):105-117

NAL Call No. QL614 J68

The reproductive cycle of *C. lavaretus* in Loch Lomond, Scotland, was investigated by monthly sampling. Spawning takes place during the first 3 weeks of Jan, on offshore gravel banks. Males congregate on the spawning-grounds throughout the spawning period, while ripe female cruise in unisexual shoals in deeper water. Individual female migrate to the spawning-grounds as ovulation takes place, spawn, and return to deep water. After spawning, the gonadosomatic ratio and somatic condition factor of both sexes decrease until June or July. Gonad recrudescence occurs in male between July and Oct, and in female between July and Dec. The somatic condition factor of both sexes rises from its minimum in June or July to its maximum in Sept. A competitive protein binding assay was used on determine cortisol levels in 0.1ml plasma samples of individual fish. The lowest cortisol levels occurred in fish caught by seine-netting and killed immediately by anaesthesia in MS 222 (Sandoz). Seine-netting and killing by concussion induced high cortisol levels, in the range of 3-5  $\mu$ g/100ml. Cortisol levels in fish caught by gill-netting for 18h were 3-6 times higher than in seine-netted fish, and the method of killing was immaterial in this case. The length of time spent in the gill-net had no significant effect on cortisol level, but maintenance of the fish in aquaria for 24-80h elicited high cortisol levels of >50  $\mu$ g /100ml. Post-mortem delay before blood-sampling resulted in lowered cortisol levels. Seasonal variations in cortisol level were determined in gill-netted fish throughout the year, and in seine-netted fish when available. Cortisol levels were high in both sexes in Sept; and very high in ovulating female caught on the spawning-grounds, though not in ovulating female caught off the spawning-grounds.

*Descriptors:* reproduction, seasonal variations, blood, spawning, life cycle, *Coregonus lavaretus*, British Isles, Scotland, Lomond L

ASFA; Copyright © 2003, FAO

Goping G, Pollard HB, Adeyemo OM, Kuijpers GAJ (1995) **Effect of MPTP on dopaminergic neurons in the goldfish brain: a light and electron microscope study.** *Brain Research.* 687:35-52

*Descriptors:* neurobiology, dopaminergic neurons, MPTP, goldfish, CNS, microscopy

Guthrie DM (1983) **Integration and control by the central nervous system.** In: *Control Processes in Fish Physiology* (ed. by J.C. Rankin, T.J. Pitcher & R.T. Duggan), pp. 130-154. Croom Helm, London

*Descriptors:* neurobiology, physiology, CNS, fish

Hall KC, Bellwood DR (1995) **Histological effects of cyanide, stress and starvation on the intestinal mucosa of *Pomacentrus coelestris*, a marine aquarium fish species.** *Journal of Fish Biology.* 47(3):438-454

NAL Call No. QL614 J68

The histological effects of cyanide, stress and starvation on the gastrointestinal tract of *Pomacentrus coelestris*, a common marine aquarium fish species, were investigated. Neither anaesthetic cyanide nor stress were found to have any detectable effects on the mucosal lining of the intestine. However, starvation resulted in a significant reduction in the intestine length, the surface area of the intestinal mucosa and the mucosal thickness, all occurring within 13 days.

*Descriptors:* histology, cyanides, digestive system, *Pomacentrus coelestris*, biological stress, aquariology

ASFA; Copyright © 2003, FAO

Hatta K, Korn H (1999) **Tonic inhibition alternates in paired neurons that set direction of fish escape reaction.** *Proceedings of the National Academy of Sciences of the United States of America.* 96:12090-12095

*Descriptors:* neurobiology, behaviour, fish, tonic inhibition

Hildebrand M (1995) *Analysis of Vertebrate Structure, Fourth edition.* John Wiley & Sons, Inc., New York

*Descriptors:* anatomy, physiology, neurobiology, fish

Hon WK Ng TB (1986) **Hormones with adrenocorticotropic and opiate-like activities from the carp (*Cyprinus carpio*) pituitary.** *Comparative Biochemistry and Physiology.* 85C:443-448

NAL Call No. QP1 C6

*Descriptors:* physiology, hormones, pituitary, adrenocorticotropic, opiate, carp, *Cyprinus carpio*

**Horsberg TE (1994) Experimental methods for pharmacokinetic studies in salmonids.***Annual Review of Fish Diseases.* 4:345-358

NAL Call No. SH171 A56

Many aspects of the use of chemical agents to combat diseases in aquaculture should be based on a firm knowledge of their pharmacokinetic behaviour in fish. The environmental conditions (temperature, salinity, pH etc.) under which kinetic studies are conducted, may vary greatly. Pharmacokinetic experiments to determine the rate and magnitude of absorption from water or feed, distribution, qualitative and quantitative metabolism and excretion in fish under various environmental conditions, are important for the determination of correct dosage regimens and withdrawal periods. These studies are often technically very difficult to carry out. Several techniques and experimental designs for different kinetic experiments are described in this review. Techniques requiring considerable manipulation of the fish, such as anaesthesia, catheterisation, cannulation, and immobilisation in metabolism chambers, will subject the fish to significant stress, which in turn may influence the data generated. The parameters reported thus often show considerable divergence. The influence of the experimental design on the results obtained has rarely been studied or addressed in papers describing pharmacokinetic studies in fish. In future studies, more attention should be paid to validation of the experimental methods.

*Descriptors:* fish culture, fish diseases, disease control, pharmacology, drugs, Salmonidae, environmental factors

ASFA; Copyright © 2003, FAO

**Hussain MG (1998) Manipulation of chromosomes in fish: Review of various techniques and their implications in aquaculture.***Bangladesh Journal of Fisheries Research.* 2(1):99-108 ISSN: 1026-6690

Human ingenuity has made it possible to advent the chromosome manipulation techniques to produce individuals with differing genomic status in a number of fish using various causal agents such as physical shocks (temperature or hydrostatic pressure), chemical (endomitotics) and anaesthetic treatments either to suppress the second meiotic division shortly after fertilization of eggs or to prevent the first mitotic division shortly prior to mitotic cleavage formation. This results in the induction of polyploidy (triploidy and tetraploidy), gynogenesis (both meiotic and mitotic leading to clonal lines) and androgenesis in fish population. The rationale for the induction of such ploidy in fish has been its potential for generating sterile individuals, rapidly inbred lines and masculinized fish, which could be of benefit to fish farming and aquaculture. In this paper, these are critically reviewed and the implication of recently developed chromosome manipulation techniques to various fin fishes is discussed.

*Descriptors:* aquaculture techniques, fish culture, biotechnology, reproduction, chromosomes, cell division, fish eggs, polyploids, gynogenesis, androgenesis, clones, hybrid culture

ASFA; Copyright © 2003, FAO

Jansen GA, Green NM (1970) **Morphine metabolism and morphine tolerance in goldfish.** *Anesthesiology* 32:231-235

*Descriptors:* neurobiology, physiology, morphine, goldfish

Jerrett AR, Stevens J, Holland AJ (1996) **Tensile properties of white muscle in rested and exhausted chinook salmon (*Oncorhynchus tshawytscha*).** *Journal of Food Science.* 61(3):527-532

NAL Call No. 389.8 F7322

After 40 hr storage at 2°C, the tensile strength of “rested” king salmon (*Oncorhynchus tshawytscha*) “white” muscle was 2.7 times that of the “exhausted” muscle with the “rested” muscle retaining its immediate post-capture strength. A combination of behavioral conditioning, conservative handling practices and chemical anaesthesia (AQUI-S™) was used to minimize the extent of pre-mortem exercise and thereby provide “rested” fish. Postmortem electrical stimulation of the “rested” animals was used to produce “exhausted” muscle. This study highlights the importance of reducing pre-harvest exercise in the production of high quality fish muscle.

*Descriptors:* muscles, mechanical properties, *Oncorhynchus tshawytscha*, storage effects, human food, fish handling, quality control, tensile strength

ASFA; Copyright © 2003, FAO

Kebus MJ, Collins MT, Brownfield MS, Amundson CH, Kayes TB, Malison JA (1992) **Measurement of resting and stress-elevated serum cortisol in rainbow trout *Oncorhynchus mykiss* in experimental net-pens.** *Journal of the World Aquaculture Society.* 23(1):83-88

NAL Call No. SH138 W62

A commercially available heterogeneous, solid-phase tube enzyme-linked immunoassay (ELISA) was modified and validated for the measurement of serum cortisol in rainbow trout *Oncorhynchus mykiss*. The assay is accurate and precise. Resting and stress-elevated serum cortisol concentrations were measured in rainbow trout with a sensitivity of 1.5 ng/ml. Fish held in net-pens at a density of 0.4 kg/m<sup>3</sup>/cm had a resting cortisol level of 16.5 ± 3.8 ng/ml (mean ± SE). At 3 h post-disturbance, serum cortisol levels were not affected by the removal of fish from adjacent net-pens with dip nets or by the use of 200 mg/L tricaine methanesulfonate (MS-222) as an anesthetic for obtaining samples. However, an acute stress (60 s removal from water) elevated serum cortisol levels to 73.7 ± 9.4 ng/ml.

*Descriptors:* fish culture, cage culture, biological stress, bioassays, serum, *Oncorhynchus mykiss*, ELISA, corticosteroids

ASFA; Copyright © 2003, FAO

Kikuchi T, Sekizawa Y, Ikeda Y, Ozaki H (1974) **Behavioral analyses of the central nervous system depressant activity of 2-amino-4-phenylthiazole upon fishes.** *Bulletin of the Japanese Society of Scientific Fisheries.* 40(4):325-337

NAL Call No. 414.9 J274

According to the modified McFarland's criterion and the diagrammatical display procedure, behavioural analyses of the central nervous system depressant activity of 2-amino-4-phenylthiazole, a piscine anesthetic, were carried out. Carp (*Cyprinus carpio*) as a representative of a fresh water type, rainbow trout (*Salmo gairdnerii irideus*) as a mid type between fresh and salt water and yellowtail (*Seriola quinqueradiata*) as a salt water type were used. The analyses resulted in establishing a methodological standardization procedure for the application of anesthetics upon a given fish for handling and transportation for aquacultural use. For the bathing anesthetization of carp, a conc of 30-40 ppm provided good anesthesia for 20-40 min. For the bathing sedation, a conc at 12 ppm provided good sedation for 3-72 hr. For the bathing anesthetization of rainbow trout, a conc at 20-30 ppm provided good anesthesia for 40 min to 3 hr and for the bathing sedation, a conc at 10 ppm provided good sedation for 24 hr. For the bathing anesthetization of yellowtail, a conc at 15-20 ppm provided good anesthesia for 10-25 min. For the bathing sedation, a conc at 8 ppm provided good sedation for 4.5 hr.

ASFA; Copyright © 2003, FAO

*Descriptors:* 2-amino-4-phenylthiazole, CNS, neurobiology, anesthesia, anesthetic, fish

Kotrschal K, van Staaden MJ, Huber R (1998) **Fish brains: evolution and environmental relationships.** *Reviews in Fish Biology and Fisheries.* 8:373-408

*Descriptors:* neurobiology, CNS, evolution, fish

Le Moal M, Simon H (1991) **Mesocorticolimbic dopaminergic network: functional and regulatory roles.** *Physiological Reviews.* 71:155

NAL Call No. 447.8 P563

*Descriptors:* neurobiology, mesocorticolimbic dopaminergic network, physiology

Lett BT, Grant VL (1989) **The hedonic effects of amphetamine and pentobarbital in goldfish.** *Pharmacology Biochemistry and Behavior.* 32:355-356

NAL Call No. QP901 P4

*Descriptors:* biochemistry, goldfish, amphetamine, pentobarbital

Matthews G, Wickelgren WO (1978) **Trigeminal sensory neurons of the sea lamprey.** *Journal of Comparative Physiology* 123:329-333

NAL Call No. 444.8 Z3

*Descriptors:* physiology, trigeminal, neurobiology, sea lamprey

Mattioli R, Aguilar C, Vasconcelos L (1995) **Reinforcing properties of the neuropeptide substance P in *Carassius auratus*: evidence of dopaminergic system involvement.**

*Pharmacology Biochemistry and Behavior* 50:77-81

NAL Call No. QP901 P4

*Descriptors:* neurobiology, substance P, dopaminergic system, neuropeptide, *Carassius auratus*

Mattioli R, Santangelo EM, Costa ACC, Vasconcelos L (1997) **Substance P facilitates memory in goldfish in an appetitively motivated learning task.** *Behavioural Brain Research*. 85:117-120

*Descriptors:* goldfish, neurobiology, behaviour, substance P, neuropeptide

*Descriptors:* goldfish, neurobiology, behaviour, substance P, neuropeptide

Mok EYM, Munro AD (1998) **Effects of dopaminergic drugs on locomotor activity in teleost fish of the genus *Oreochromis* (Cichlidae): involvement of the telencephalon.**

*Physiology and Behavior*. 64:227-234

NAL Call No. QP1 P4

*Descriptors:* telencephalon, physiology, neurobiology, dopaminergic drug, teleost, *Oreochromis*

Mueller R (1976) **Investigations on the body temperature of freshwater fishes.** *Arch. fuer Fischereiwissenschaft* 27(2):1-28

NAL Call No. SH1 A72

Body temps of brown trout, rainbow trout, perch, pike, chub, barbel and eel have been measured using orally and surgically implanted temp transmitters. Temps of resting fish did not differ significantly from the temp of the ambient water. Vigorous struggling in a net caused the muscle temp to rise to a maximum of 0.72°C above ambient. During continuous swimming in the fish wheel the body temp did not rise substantially, but after swimming, moderate temp rises were usually observed. Adjustment of body temp after activity to the water temp took place within 20 to 100 minutes. Feeding increased the body temp mainly in conjunction with swimming activity. Time for body temp adaptation in living fish after thermal shock is two thirds of that observed in dead fish, which again depends on a body wt-length relation. Blood circulation intensity is essential for thermal exchange in large fish and can be influenced by an anaesthetic (MS222). Under normal conditions, no specific differences in thermal regime were found among the fish spp tested.

*Descriptors:* water temperature, temperature effects, methodology, body temperature, thermoregulation, length-weight relationships, blood circulation, controlled conditions, Pisces, *Anguilla anguilla*, *Leuciscus*, *Barbus*, *Perca fluviatilis*, *Esox lucius*, *Oncorhynchus mykiss*, *Salmo trutta*

ASFA; Copyright © 2003, FAO

Munro AD (1986) **The effects of apomorphine, *d*-amphetamine and chlorpromazine on the aggressiveness of isolated *Aequidens pulcher* (Teleostei, Cichlidae).**

*Psychopharmacology* 88:124-128

*Descriptors:* apomorphine, d-amphetamine, chlorpromazine, psychopharmacology, teleost, *Aequidens pulcher*, neurobiology

Munro AD, Dodd JM (1983) **Forebrain of fishes: neuroendocrine control mechanisms.** In: *Progress in Nonmammalian Brain Research, Volume III* (ed. by G. Nisticò & L. Bolis), pp. 2-78. CRC Press Inc, Florida

*Descriptors:* neurobiology, CNS, neuroendocrine control, fish

Ng TB, Chan TH (1990) **Adrenocorticotropin-like and opiate-like materials in the brain of the red grouper *Epinephelus akaara* (Teleostei: serranidae).** *Comparative Biochemistry and Physiology.* 95C:159-162

NAL Call No. QP1 C6

*Descriptors:* neurobiology, adrenocorticotropin-like, opiate-like, CNS, red grouper, teleost, *Epinephelus akaara*

Pearson MP, Stevens ED (1991) **Size and hematological impact of the splenic erythrocyte reservoir in rainbow trout, *Oncorhynchus mykiss*.** *Fish Physiology and Biochemistry* 9(1):39-50

NAL Call No. QL639.1.F583

Rainbow trout (*Oncorhynchus mykiss*) were sampled individually, at rest, following air exposures of up to 8 min, during recovery from a 5 min air exposure or after a 5 min chase. The spleen was photographed in vivo at rest and following 5 min air exposure in one fish. The effect of individual versus serial sampling from the same tank and of MS222 anaesthesia was also examined. Spleen hemoglobin content (SpHb), spleen somatic index (100 x spleen weight/body weight; SSI), blood hemoglobin concentration (Hb), and hematocrit (Ht), were measured. Mean cell hemoglobin concentration (MCHC), erythrocyte reservoir size, and relative contributions of reservoir release, erythrocyte swelling, and plasma water loss to hemoconcentration were calculated.

*Descriptors:* erythrocytes, spleen, fish physiology, body weight, *Oncorhynchus mykiss*, *Salmo gairdneri*, haemoglobins, somatic index

ASFA; Copyright © 2003, FAO

Piddington RW (1971) **Central control of auditory input in the goldfish. 2. Evidence of action in the free-swimming animal.** *Journal of Experimental Biology.* 55(3):585-610

NAL Call No. 442.8 B77

(1) In the free-swimming electrode-implanted goldfish, the neural response in the medulla to a constant auditory stimulus may exhibit reversible fluctuations in amplitude which are

abolished by anaesthesia. (2) The results are consistent with the action of an auditory control system which can reduce or enhance the input following a click. (3) Noise-masking effects and reflex muscular control were excluded by demonstrating the relative constancy of the rectified microphonic during simultaneous changes in the clic-evoked action potential at the medulla. (4) There are 3 kinds of response modification: habituation, rapid inhibitory feedback, and facilitation. (5) Both feedback and habituation act predominantly on high-threshold auditory fibres. Low-threshold fibres do not become habituated, and dishabituation does not occur. (6) As in the mammal, anaesthetic reduces the tendency of the system to become habituated by an amount which depends on the dosage. Auditory fibres with highest threshold have the greatest tendency to become habituated and are the least affected in this respect by anaesthetic. (7) Simple conditioning experiments indicate that control influences exerted over the input can be biased by positive or negative reinforcement which follows the auditory stimulus. (8) The control system may work in attention, in frequency analysis, or in suppressing input to self-made sounds. (9) A new hypothesis is made on the biological significance of hearing in fish. A fish may be able to tell if other swimming fish are approaching, receding, or moving tangentially by analysing the proportions in time of the compressions and rarefactions present in the swimming sounds, which are proposed to be asymmetrical.

ASFA; Copyright © 2003, FAO

*Descriptors:* goldfish, audition, hearing, neurobiology, medulla

Saliou A (1980) *Contribution to the study of the inert gas narcosis and high pressure nervous syndrome. Respective effects of the hydrostatic pressure and of the inert hyperbaric pressure.* 103 pp

This thesis studies the hydrostatic pressure effects until 151 atm on the trout (*Salmo trutta*) in experimental conditions. The high pressure effects of several inert gases (nitrogen, helium, argon) are examined by observing the respiratory ventilation, the nervous regulation and the heart rhythm. Some anesthetic substances first at barometric pressure, then at hydrostatic pressure are used to compare their narcotic effects on the fish physiology and behavior. The methodology and experimental conditions are described.

*Descriptors:* pressure effects, rare gases, helium, nitrogen, argon, nervous system, heart, respiration, physiology, *Salmo trutta*

ASFA; Copyright © 2003, FAO

Sills JB, Allen JL (1971) **The influence of pH on the efficacy and residues of quinaldine.** *Transactions of the American Fisheries Society.* 100(3):544-545

NAL Call No. 414.9 Am3

Quinaldine, an anaesthetic for fish, loses its effectiveness in solutions having pH values < 6. Measured quantities of un-ionized quinaldine in solution compared favourably with calculated values at selected pHs. Quinaldine residues in fish and un-ionized quinaldine in

solution were measured by gas chromatography.

ASFA; Copyright © 2003, FAO

*Descriptors:* pH, quinalidine, anesthetic, fish

Sneddon LU, Braithwaite VA, Gentle MJ (2003) **Do fish have nociceptors: Evidence for the evolution of a vertebrate sensory system.** *Proceedings of the Royal Society: Biological Sciences.* 270(1520):1115-1121

*Society: Biological Sciences.* 270(1520):1115-1121

URL: <http://gessler.ingentaselect.com/vl=2030559/cl=122/fm=docpdf/nw=1/rpsv/cw/rs/09628452/v270n1520/s2/p1115>

*Descriptors:* fish, pain, nociception, trout, teleost, CNS, behaviour, physiology, noxious stimuli

Stobo WT (1972) **Effects of formalin on the length and weight of yellow perch.**

*Transactions of the American Fisheries Society.* 101(2):362-364

NAL Call No. 414.9 AM3

Data for fish growth studied often derive from formalin preserved specimens, but little information is available on the effect of the preservation on spiny-rayed fishes. The effect of 10% formalin on length and weight of yellow perch (*Perca flavescens*) was checked during an 18.5 months period. 55 perch were left in anaesthetic solution (0.8% ethylether) until death. Length and weight were recorded prior to death, after 1 hour, then after 1 hour in formalin. Observations were repeated on a geometric time scale for 1 week, weekly for 1 month, then monthly for 7 months and finally 18.5 months after killing. Tabled results show immediate shrinkage in small fish, largely complete in 24 hour but an initial increase in large fish with subsequent shrinkage complete in 5 days. No length corrections are thought necessary for preserved perch. In all perch weight showed an initial rapid increase, which slowed for a short period, then a protracted period of increase followed by a period of decrease (135 to 557 days).

ASFA; Copyright © 2003, FAO

*Descriptors:* formalin, yellow perch, spiny-ray fishes, preservative, anesthetic

Teo Leng-Hong, Chen Ti-Wen (1993) **A study of metabolic rates of *Poecilia reticulata* Peters under different conditions.** *Aquaculture Fish Management.* 24(1):109-117

NAL Call No. SH1 F8

The aim of this work was to investigate the factors that affect the metabolic rates of guppies, *Poecilia reticulata*, by measuring the oxygen uptakes of guppies individually or in groups in closed vessels to simulate the actual packaging conditions. Metabolic rates of guppies increased with the increase of temperatures. Anaesthetic, 2-phenoxyethanol, suppressed the oxygen consumption rates. Grouped fish also showed lower metabolic rates than individual fish. Light and starvation did not produced any effect. The pH of the water, ammonium and carbon dioxide concentrations had significant effects on the metabolic rates

of guppies.

*Descriptors:* animal metabolism, controlled conditions, *Poecilia reticulata*, environmental factors, oxygen consumption, group effects, light effects, starvation, pH effects, temperature effects, ornamental fish, fish handling, metabolic rate  
ASFA; Copyright © 2003, FAO

Torres P, Tort L, DePauw N, Joyce J (1991) **Effects of stress and metal exposure on blood parameters and liver metabolism in rainbow trout.** *Aquaculture and the Environment, Special Publication, (European Aquaculture Society)*. 14: 312-313  
NAL Call No. SH138.S64

Amongst the main toxicants for fish, heavy metals have been shown to induce a wide range of effects including changes in respiratory and haematological parameters or energetic resources. At the same time, molecular responses can also be detected such as induction of metallothioneins in liver, low molecular metal-binding proteins involved in heavy metal detoxification. The occurrence of heavy metal contamination can be related as well to an stressing situation, since the consequences of contamination lead to similar changes in some particular physiological indicators (Torres et al. 1986). Moreover it has been shown that both metal treatment and stress would rise the degree of lipid peroxidation due to an increase in free radical production. In this work we try to correlate the fish responses to both metal toxic concentrations and handling stress by analyzing a number of metabolic, physiological or molecular parameters. Thirty-two rainbow trout (*Oncorhynchus mykiss*) obtained from a fish farm were divided in four experimental groups corresponding to control, injected intraperitoneally with saline, injected with cadmium 20 ppm as cadmium chloride and stressed. The stress procedure consisted in handling stress by holding the fishes in the net out of the tank during a period of 10 sec. and repeating this three times a day during one week. After experimental treatments fish were subjected to anaesthesia with phenoxiethanol. Blood (1.5 to 2 ml) was taken off in less than 1 minute. The liver was then excised and the fish weighed and measured. Routine haematological analysis were performed and the concentration of total proteins, glucose and cortisol were determined from plasma. From liver tissue the levels of hepatic protein, metallothionein, thiol groups, peroxides and zinc were determined.

*Descriptors:* biological stress, pollution effects, heavy metals, water quality, aquaculture facilities, fish culture, hematology, *Oncorhynchus mykiss*  
ASFA; Copyright © 2003, FAO

Tort L, Flos R, Hughes GM (1986) **Methods for studying effects of pollutants on cardiorespiratory physiology in fish.** *Informes Tecnicos. Instituto de Investigaciones Pesqueras., Barcelona*. No. 131. 32 pp

Pollutant substances mobilized from industrial and densely populated areas have been shown to affect the environment, fish being one of the most affected groups. A variety of

methods and techniques regarding respiratory, hematological and cardiovascular physiology are reviewed. Other significant aspects such as anaesthesia, anticoagulants and stress are also included.

*Descriptors:* pollution effects, analytical techniques, respiration, blood circulation, hematology, fish

ASFA; Copyright © 2003, FAO

Yamamori K, Hanyu I, Hibiya T (1971) **Electrocardiography of the eel by means of underwater electrodes.** *Bulletin of the Japanese Society of Scientific Fisheries.* 37(2)94-97  
NAL Call No. 414.9 J274

In the eel, *Anguilla japonica*, which has a heart with a strong electromotive force, the ECGs were found to be recordable by electrodes placed in the water apart from fish's body. An apparatus so devised that an 'underwater electrode' was attached to either end of a plastic cylinder was submerged on the bottom of an aquarium. When the fish slipped into the cylinder, ECGs were easily recorded, being superimposed upon slow undulation of the base line caused by the respiratory movement of the fish. QRS complex of the ECG was marked, while P and T waves were identified with difficulty. The amplitude of QRS complex was about 0.5 mV. This method enabled us to observe the heart rate of the eel under least disturbed state. Ordinary heart rate was not quite regular. Very slight stimulation was enough to bring about cardiac inhibition, which was also accompanied by a considerable reduction in the amplitude of the QRS. After rough treatment, such as deep anaesthesia or exposure to air, the heart rate showed remarkable compensatory increase, reaching a value a few times higher than the normal level. In the American eel, *A. rostrata*, QRS was approximately 0.02 mV. This indicates that the electromotive force of the heart in this sp is much smaller than in *A. japonica*.

ASFA; Copyright © 2003, FAO

*Descriptors:* eel, *Anguilla japonica*, *Anguilla*, underwater electrodes, ECG, anesthesia, electrocardiography

## ***Web Resources:***

**Aspects of Animal Welfare and Aquaculture - A Compendium of Selected Literature** by Richard D. Moccia and Kristopher P. Chandroo; Aquaculture Centre, University of Guelph, Guelph, Ontario, Canada

<http://www.aps.uoguelph.ca/~aquacentre/aec/publications/welfare-bib.html>

Return to: [Contents](#) OR [Top of Document](#)